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# Tillage and Crop Rotation Management Impact on Yield and Soil Quality

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## **Tillage and crop rotation management impact on yield and soil quality**

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### **Introduction**

Tillage decision is only one concern farmers have to make every fall. There are many other factors need to be considered in selecting a tillage system for any given field or region within the state. Those factors are soil conditions, which can include, soil slope, soil drainage, topsoil depth or the A-horizon depth. Other factors need to be considered, which are equally important such as hybrid selection, crop rotation, and management factors, such as, residue cover, type of residue (corn or soybean), soil moisture condition at the time of making the decision, timing of tillage operation, fertilizer management in conjunction with tillage operation, type of residue management equipment, planting and harvesting equipment, compliance with conservation plans, and above all, is the economic return and benefits of selecting any tillage system.

The variability in soil conditions will be a key factor in selecting a tillage system that will influence crop response and ultimately yield expectations. However, crop response to tillage systems has been demonstrated to be different for the same tillage system in a different part of the state or different regions elsewhere. Different tillage systems affect soil temperature, soil moisture conditions, soil compaction, soil productivity, and nitrogen movement and N availability differently. These effects will be indicated in crop response to different tillage systems, where soil temperature plays a significant role in early seed germination, organic N mineralization, nutrient and residue incorporation, and weed and pest control.

Understanding site specific effect of tillage can help significantly reducing input cost and reduce the negative impact on water, air, and soil quality. Conservation tillage systems continue to be a very important component of a crop production system in terms of economic return and environmental benefits. However, the challenges in managing such systems, and namely no-tillage, are related to the proper management practices, such as the availability of drainage in poorly drained soils, use of residue management residue attachments, seeding depth, and fertilizer management. Also, the timing of conducting field operations, N application, manure injection, etc., has to be done when soil moisture condition is below field capacity to avoid serious soil compaction problems.

Soil moisture and soil temperature conditions in the seedbed zone (top 2-6 inches) can promote or delay seed germination and plant emergence (Kaspar et al., 1990; Schneider and Gupta, 1985). Therefore, healthy plant growth and development require soil conditions that have adequate soil moisture and minimal root penetration resistance (Phillips and Kirkham, 1962). Soil temperature can be affected by surface residue cover, causing cooler surface soil temperature and slower soil drying in the spring (Fortin, 1993; Kaspar et al., 1990) in spite of reducing soil erosion and surface runoff (Cruse et al., 2001). Removal of residue from the row can reduce in-row soil moisture content in the seedbed, while conserving interrow soil moisture. Unlike soil moisture, soil temperature has an inverse relationship with the amount of residue cover.

Tillage systems have a significant effect on N dynamics by affecting N pools in the soil system. Soil disturbance during the tillage process and the incorporation of surface residue increases soil aeration, which can increase the rate of residue decomposition (McCarthy et al., 1995).



This process impacts soil organic N mineralization whereby readily available N for plant use is increased (Dinnes et al., 2002). The type of tillage system can influence the amount of N available for loss in the soil profile. Deep accumulation of  $\text{NO}_3\text{-N}$  in the soil profile represents a potential for  $\text{NO}_3\text{-N}$  leaching into shallow water tables (Keeney and Follett, 1991).

## Results and discussion

### *Productivity and profitability*

A long-term study comparing different tillage and crop rotation systems across Iowa showed that no-tillage corn and soybean yields were competitive with moldboard plowing, deep-rip, chisel plowing, and ridge tillage for more than 8 years after no-tillage was established (Al-Kaisi and Yin, 2004; Yin and Al-Kaisi, 2004). No-tillage typically yielded 5 percent less, especially in poorly drained areas compared to other tillage systems. However, the economic return of different tillage systems showed no-tillage had an advantage over other tillage systems due to the lower input cost associated with no-tillage (Table 1) (Al-Kaisi and Yin, 2004; Yin and Al-Kaisi, 2004). On average, No-tillage system reduced input cost for corn production by approximately \$18/acre under corn-soybean rotation and \$18.50/acre for corn following corn compared to all conventional tillage systems (Table 1). These input costs in Table 1 did not include the land cost and they may vary from one farm to another based on level of management and other additional inputs. No-tillage shows saving in input cost for soybean production of \$12/acre compared to conventional tillage systems as well. At the mean time, conventional tillage systems show no advantages in soybean yield over no-tillage across the state (Tables 2-5).

In a more recent tillage study from eight locations across Iowa, no-tillage corn and soybean yields generally were not significantly different at Crawfordsville and Kanawha (Tables 2 through 5). This is encouraging for producers who are reluctant to switch to no-tillage due to concerns of poor crop performance. An effective no-tillage system depends on properly selecting and setting up the planter, adequate fertility program, and efficient drainage system especially in poorly drained soils. The success of any conservation system depends heavily on how the system is managed. Generally, conservation systems require less input costs. The advantage of conservation systems is in the fuel saving, where no-tillage generally requires one gal per acre compared to 4.1 gal per acre for conventional tillage operations. The reduction in the number of implements and horsepower needed is also a significant savings in capital and maintenance costs. Fewer trips across the field reduce the fuel and labor needed.

**Table 1.** Total production input costs per acre for different tillage systems for corn and soybean under different crop rotations.

<b>Tillage System</b>	<b>Corn after Soybean (\$/acre)</b>	<b>Corn After Corn (\$/acre)</b>	<b>Soybean After Corn (\$/acre)</b>
No-tillage	348	392	186
Strip tillage	355	399	193
Chisel Plow	366	411	196
Deep Rip	372	417	202
Moldboard Plow	366	415	201

- Input costs account for machinery costs, labor, seed, nutrients, chemicals, and insurance. Input cost does not include land rental (\$190 cash rent equivalent).
- Labor was figured at \$11.00/hr, nutrients are based on crop removal rates, and insecticides were accounted for in corn after corn.
- Herbicide tolerant soybeans were used in input costs considerations.
- Input costs based from ISU Extension publication FM 1712 and Ag Decision Maker file A1-20.

**Table 2.** Corn and soybean yields under a corn-soybean rotation at the ISU Crawfordsville Research Farm. Yields are corrected to 15.5 and 13.0% for corn and soybean respectively.

	Corn (C/s)					Soybean (c/S)				
	2003	2004	2005	2006	2007	2003	2004	2005	2006	2007
	----- bushels / acre -----									
No-Tillage	212.8	180.0	171.3	189.1	159.3	38.7	55.1	71.8	56.8	59.4
Strip-Tillage	205.9	190.7	168.3	182.1	161.1	39.5	55.9	69.8	55.1	58.9
Deep Rip	209.7	200.2	171.0	185.7	170.8	42.2	57.7	70.2	56.0	59.6
Chisel Plow	211.6	207.9	177.4	184.6	168.8	40.6	55.7	69.5	58.5	57.5
Moldboard Plow	202.7	214.1	179.2	209.3	185.9	41.7	58.3	69.8	64.6	60.1
LSD <sub>(0.05)</sub> <sup>a</sup>	16.1	22.8	13.9	25	14.8	3.2	3.3	5.4	4.2	3.5
5-Tillage Average	208.5	198.6	173.4	190.2	169.2	40.5	56.5	70.2	58.2	59.1

<sup>a</sup> Least significant differences (LSD<sub>(0.05)</sub>) are based on a Fisher test. Yield differences greater than the least significant difference are significantly different.

**Table 3.** Yields are corrected to 15.5 and 13.0% for corn and soybean respectively.

	Corn (C-c-s)	Corn (c-C-s)		Soybean (c-c-S)	
	2005	2003	2006	2004	2007
	----- bushels / acre -----				
No-Tillage	165.6	129.8	208.3	57.6	64.1
Strip-Tillage	158.8	149.2	205.4	59.7	64.0
Deep Rip	163.9	146.1	201.0	60.0	62.7
Chisel Plow	163.3	157.7	196.4	59.8	60.2
Moldboard Plow	164.3	149.4	218.4	58.8	63.2
LSD <sub>(0.05)</sub> <sup>a</sup>	8.6	25.6	10.6	2.6	2.6
5-Tillage Average	163.2	146.4	205.9	59.2	62.8

<sup>a</sup> Least significant differences (LSD<sub>(0.05)</sub>) are based on a Fisher test. Yield differences greater than the least significant difference are significantly different.



**Table 4.** Corn and soybean yields under a corn-soybean rotation at the ISU Kanawha Research Farm. Yields are corrected to 15.5 and 13.0% for corn and soybean respectively.

	Corn (C/s)				Soybean (c/S)				
	2003	2004	2005	2006	2003	2004	2005	2006	2007
	----- bushels / acre -----								
No-Tillage	187.7	172.4	136.6	189.1	38.2	56.5	54.6	63.2	56.1
Strip-Tillage	191.7	181.1	146.0	188.2	38.0	57.8	54.1	59.9	56.3
Deep Rip	190.7	188.8	181.3	191.1	39.4	57.1	53.1	57.9	58.8
Chisel Plow	198.3	192.2	189.2	190.9	39.9	56.8	52.2	59.7	56.5
Moldboard Plow	196.7	191.2	188.5	196.0	40.7	57.8	53.5	57.4	56.7
LSD <sub>(0.05)</sub> <sup>a</sup>	32.2	11.2	24.7	9.3	3.7	4.4	3.5	3.4	8.4
5-Tillage Average	193.0	185.1	168.3	191.1	39.2	57.2	53.5	59.6	56.88

<sup>a</sup> Least significant differences (LSD<sub>(0.05)</sub>) are based on a Fisher test. Yield differences greater than the least significant difference are significantly different.

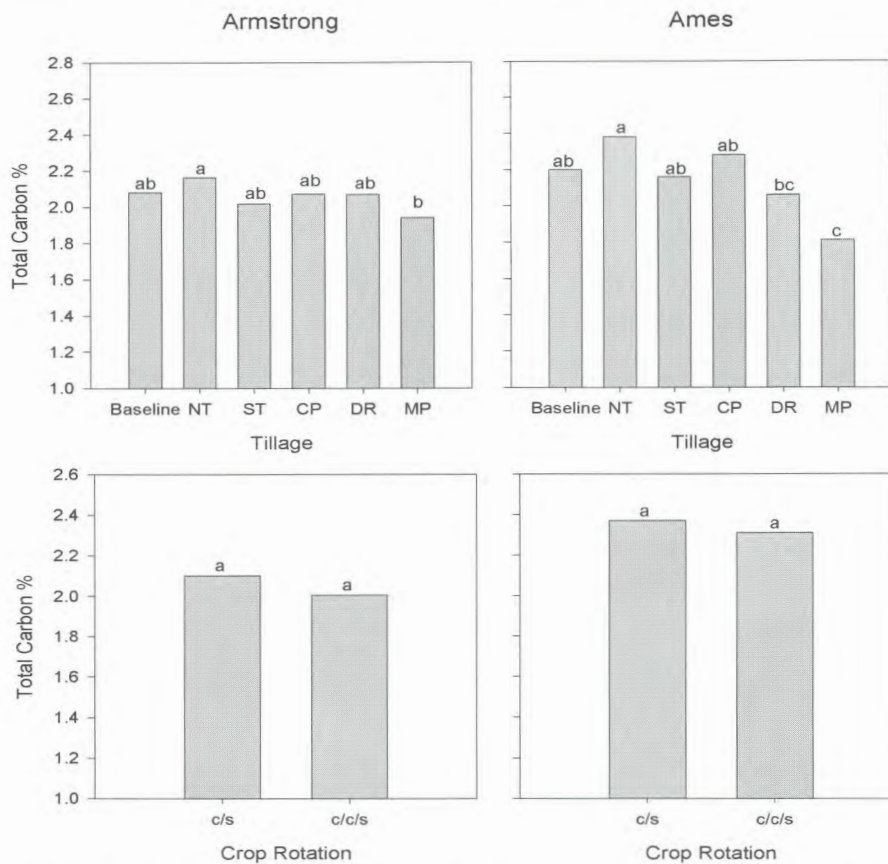
**Table 5.** Corn and soybean yields under a corn-corn-soybean rotation at the ISU Kanawha Research Farm. Yields are corrected to 15.5 and 13.0% for corn and soybean respectively.

	Corn (C-c-s)		Corn (c-C-s)	Soybean (c-c-S)	
	2004	2007	2005	2003	2006
	----- bushels / acre -----				
No-Tillage	174.1	172.8	214.0	37.4	63.4
Strip-Tillage	192.3	177.7	220.1	34.9	53.4
Deep Rip	188.5	196.8	223.2	38.9	59.4
Chisel Plow	198.6	221.9	218.3	37.5	60.5
Moldboard Plow	200.9	208.3	232.0	39.3	60.3
LSD <sub>(0.05)</sub> <sup>a</sup>	14.5	47.2	9.7	2.4	12
5-Tillage Average	190.9	191.94	221.5	37.6	59.4

<sup>a</sup> Least significant differences (LSD<sub>(0.05)</sub>) are based on a Fisher test. Yield differences greater than the least significant difference are significantly different.

### Tillage effect on soil quality

- Carbon storage: Intensive tillage operations can have negative effect on soil organic carbon by oxidizing organic matter. Results from tillage studies in Iowa shows consistent decline in organic carbon with increase intensity in tillage operations (Fig. 1). Aerating soil increases the rate of soil organic matter decomposition and emission of carbon dioxide. Soil carbon is beneficial to improve soil structure and nutrient and water holding capacity.



**Figure 1.** Soil carbon as affected by tillage and crop rotation at the top 6 inches for two sites from 2002 to 2004.

- **Erosion and water quality:** Surface residues from both corn and soybean provide protection from both wind and water erosion. Cover crops following soybean and corn silage harvest can be used to increase the amount of residue cover and stabilize the surface soil. Additionally, waterways, terraces, and buffer strips provide living protection that controls the flow of surface water runoff and allow for sediments and nutrients to settle out before leaving the field.
- **Crop residue:** The more intensive a tillage pass is, the more residue will be broken down and buried. Crop residue is important to hold surface soil in place and protect the soil surface from raindrop and wind impacts. Crop residue also helps hold snowfall in place, which in the spring will contribute to subsurface soil moisture.
- **Soil structure:** Tillage operations break soil aggregates and decrease pore spaces that are responsible for enhancing water infiltration. By switching to conservation tillage and using cover crops the soil will build better soil structure due to less soil disturbance and increased soil organic matter.
- **Soil compaction:** There is a misconception of increased soil compaction with conservation systems. Research shows, fields under conservation systems have much better developed soil structure and pore spaces than conventional systems. The improved soil structure provides soil the strength to withstand heavy field equipment load.

- Soil moisture: A major benefits of conservation systems is the enhancement of subsurface soil moisture due to improvement of soil organic matter and water holding capacity. This is critical in areas where precipitation is limited and conservation of soil moisture is a priority.

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